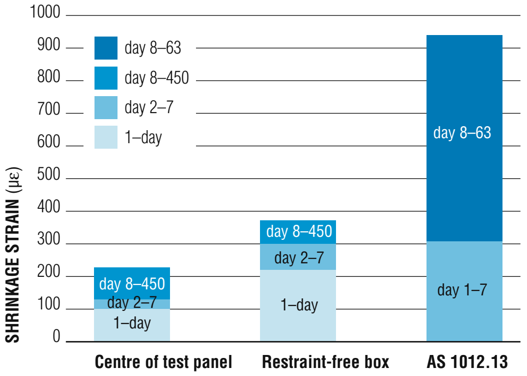
Specifying low drying shrinkage ≠ crack control

Drying shrinkage has been ineffectively used by some design engineers as a means of controlling cracking in slab construction. The AS 1012.13 drying shrinkage test measures the shortening of small concrete prisms due to drying from a water-saturated condition at the age of 7-days for various periods of drying with a standard drying period of 56 days. It therefore measures a later-age shrinkage. There are significant differences between the mechanisms and magnitude of early shrinkage and the standard drying shrinkage. It is the early-age shrinkage that influences cracking. See *Early-age Shrinkage of Concrete*.



Queensland University insitu and standard shrinkage results

Research conducted at the University of Queensland showed that a concrete with a standard drying shrinkage of 650 με, used in a slab construction, exhibited a 15-month total shrinkage strain at the centre of a test panel of around 225 με, out of which 125 με or 56% occurred in the first week. Cracking due to plastic shrinkage and plastic settlement usually occurs within the first day from casting, whereas cracking due to early thermal contraction mainly occurs within the first few weeks from casting.

In a companion restraint-free box, the same concrete exhibited a 15-month shrinkage strain of around 370 με, out of which 295 με or 80% occurred in the first week before the commencement of strain measurement in the restraint-free standard drying shrinkage test. These clearly demonstrate the standard drying shrinkage to be significantly higher than actual later-age drying shrinkage (day 8–450) and bears no relationship to the early-age shrinkage considered critical to crack control.

The results confirmed that the specification of lower standard drying shrinkage strains alone will not control or prevent the development of early-age tensile stresses that lead to early-age cracking, and that adequate protection and curing are the only means of controlling the development of restrained tensile stresses during the first few hours after casting, and hence reduce the risk of unplanned cracking (Dux et al, 2010).

In slab construction, it has long been recognised that good construction practices that reduce early shrinkage and minimise restraint are essential requirements in achieving the construction of relatively crack-free slabs (Kraai, 1982, Appleyard, 2010). Early shortening is largely due to early shrinkage and thermal contraction which can only be controlled by good mix design, proper compaction and finishing and curing. Restraint can be minimised through good sub-base grading and finishing; placement of membrane; installation of bond separation material, installation of dowel or key joints, timing of saw cut joints, and curing. See *Avoiding Early Cracking*.

In prestressed concrete design and construction, drying shrinkage limits are not as important in design as minimising restraints due to the shortening of post-tensioning slabs by vertical supporting elements. Such restraints are best controlled by positioning of the vertical elements, placement of permanent and temporary movement joints, and isolation of shear walls (Cross, 2010). In watertight structures, early slab stressing, proportioning of the concrete mix and protection of slabs during its early life are important to minimise early shrinkage. In the design of post-tensioned structural elements, the impact of drying shrinkage on long-term deflection, prestressing losses and amount of shrinkage and temperature reinforcements are of interest. The reduction of the AS 1012.13 drying shrinkage limit from 800 με to 500 με results in small 3% and 6% reductions in prestressing loss and long-term deflection respectively, and no impact on the average intensity of effective prestress in concrete (Cross, 2010).

The specification by engineers of unrealistically low standard drying shrinkage is potentially difficult to achieve as well as adversely affecting the workability of the concrete (Butcher, 2010). A careful assessment of the appropriateness of having a lower level of drying shrinkage than is commonly found in an area may avoid unnecessary costs. If lower drying shrinkage limits than would otherwise be achieved are specified, the cost of concrete will in most cases increase due to the need to use more-expensive aggregates or placing methods. This cost increase will vary from one area to another because of the different properties of the local naturally-occurring aggregate deposits.

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